

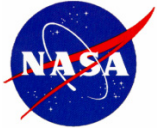


Design and Implementation of the MSL Cruise Propulsion Tank Heaters

by

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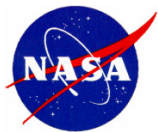
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Outline



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- Introduction
 - Analytical work to determine heater power
 - Predictions of heater performance
 - Heater design
 - Design verification and installation
 - Conclusions



Intro: Pressurized Tanks Store Hydrazine **JPL**

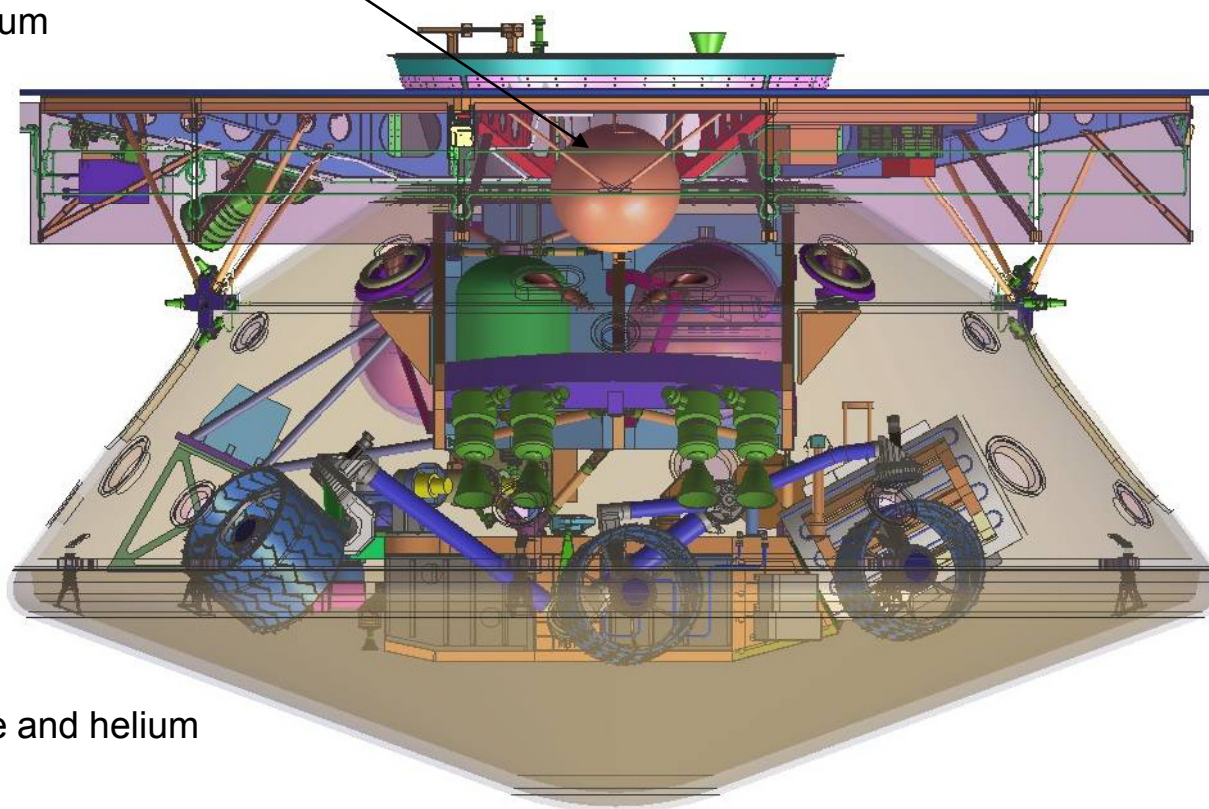
Cruise propulsion tank, 1 of 2

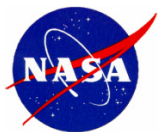
Tanks are pressurized with helium

An internal diaphragm separates the helium from the hydrazine

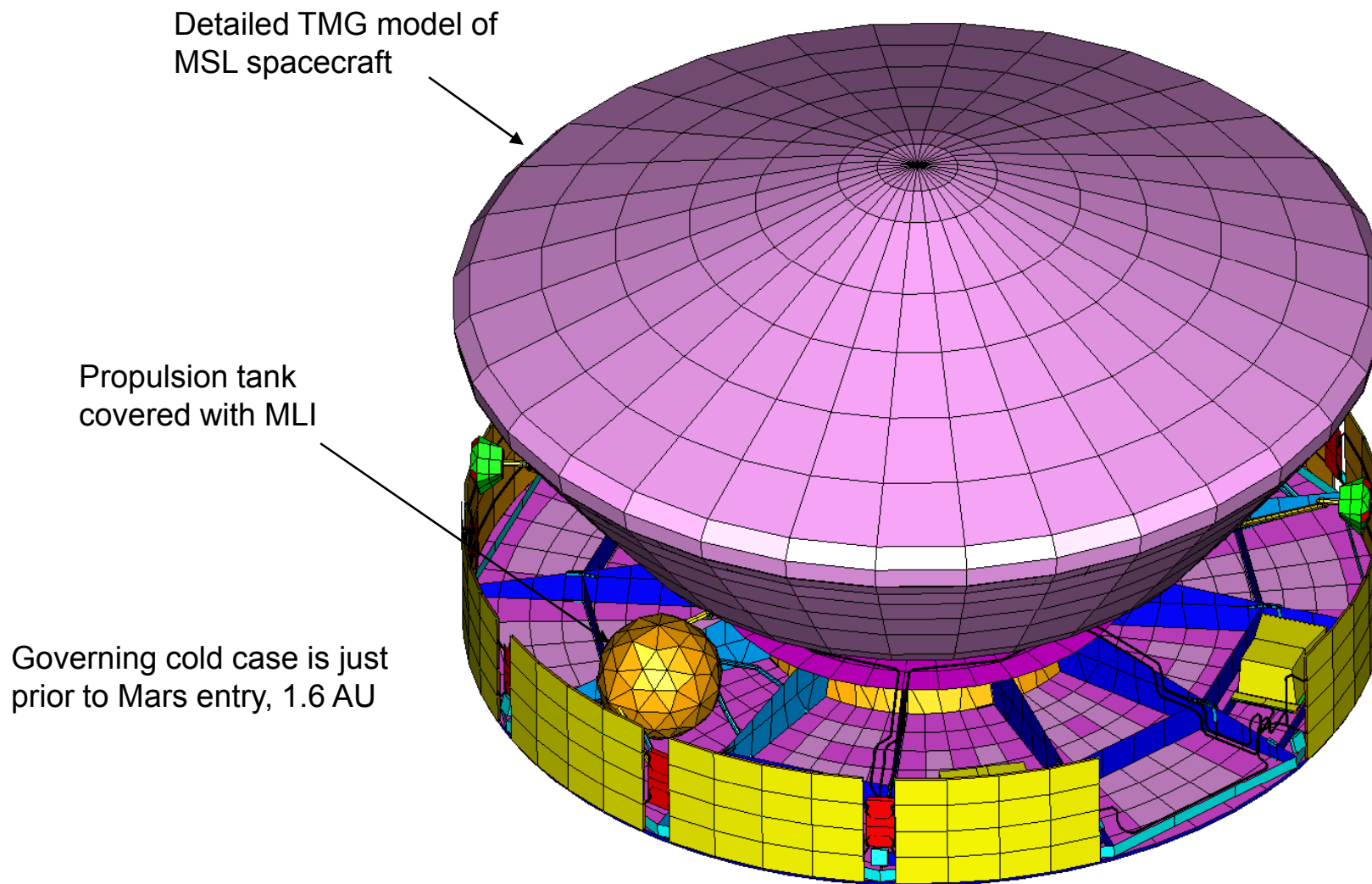
Hydrazine freezes at 2°C , similar to water.

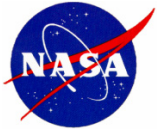
Heaters keep the hydrazine and helium at 36°C for the trip to Mars.



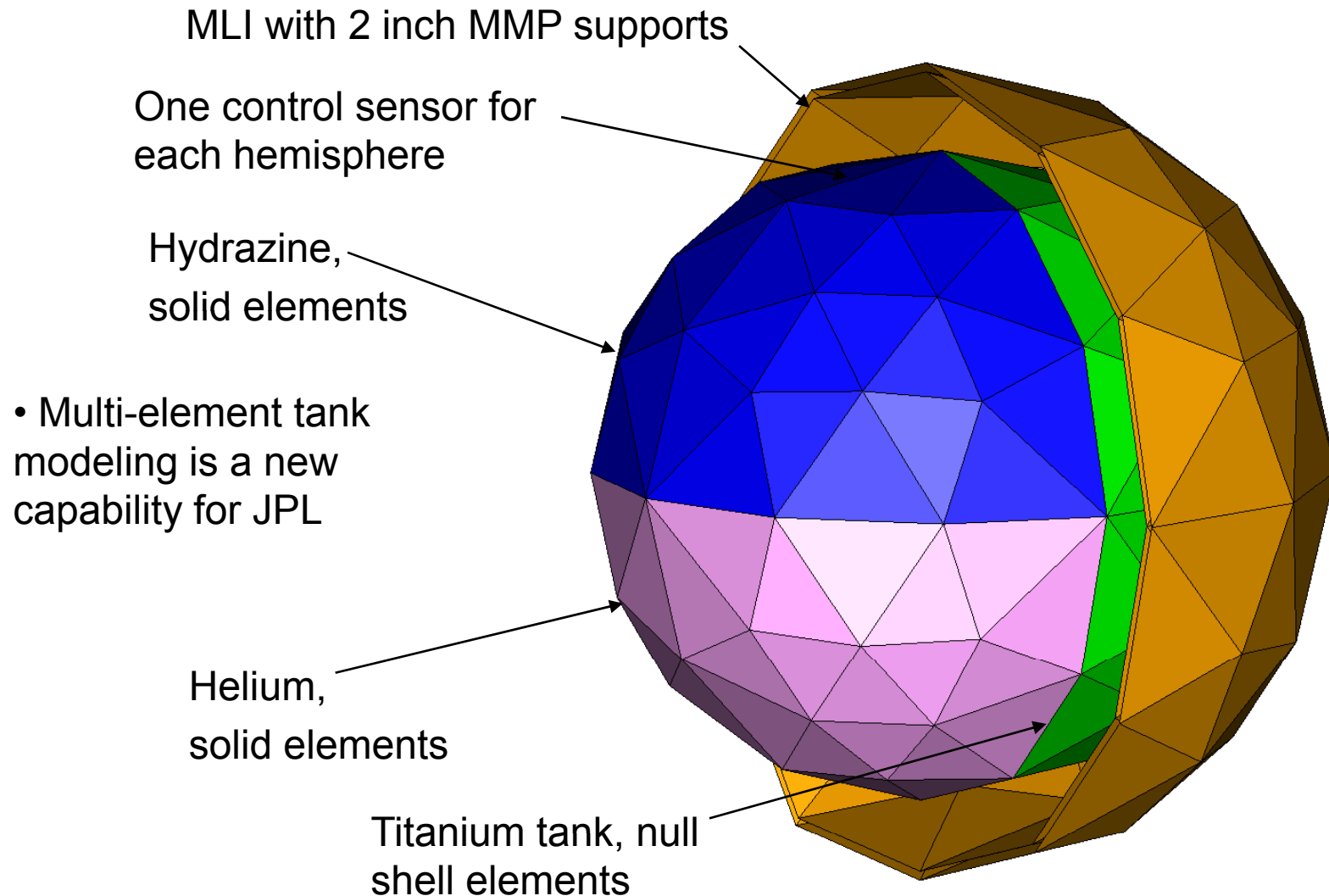


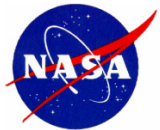
Analysis: Use TMG Model for Heat Loss Calc's





Thermal Model Simulates ½ Full Tank





Analysis yields 13W per hemisphere



- Gas and fluid conduction are significant.
 - Results with internal conduction have smaller temperature differences.
- Full, uniform heater coverage produces the smallest temperature differences.
- Install 13W at 22V for both tank circuits (35W at 36V)
- Provide as close to full heater coverage as practical.



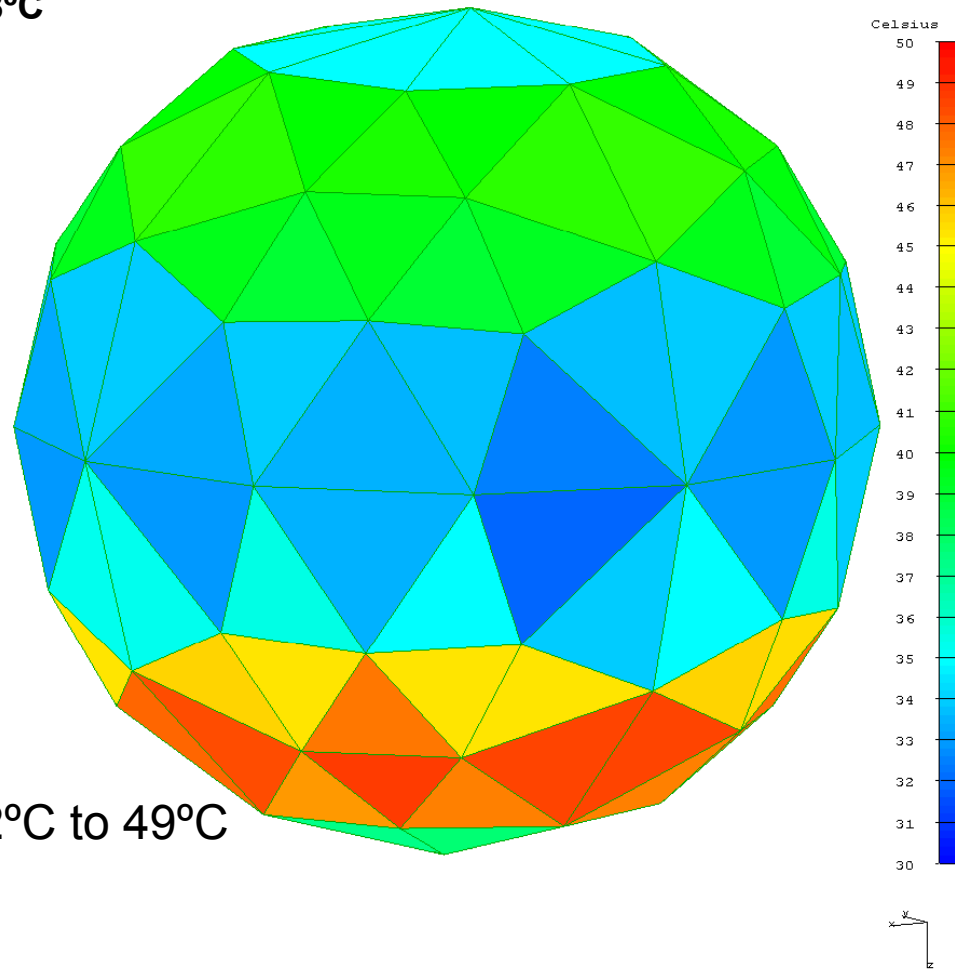
Predictions: Cold Temperatures Acceptable



Cold Case: 493W/m² at 45° sun angle
Control points: 34°C to 38°C

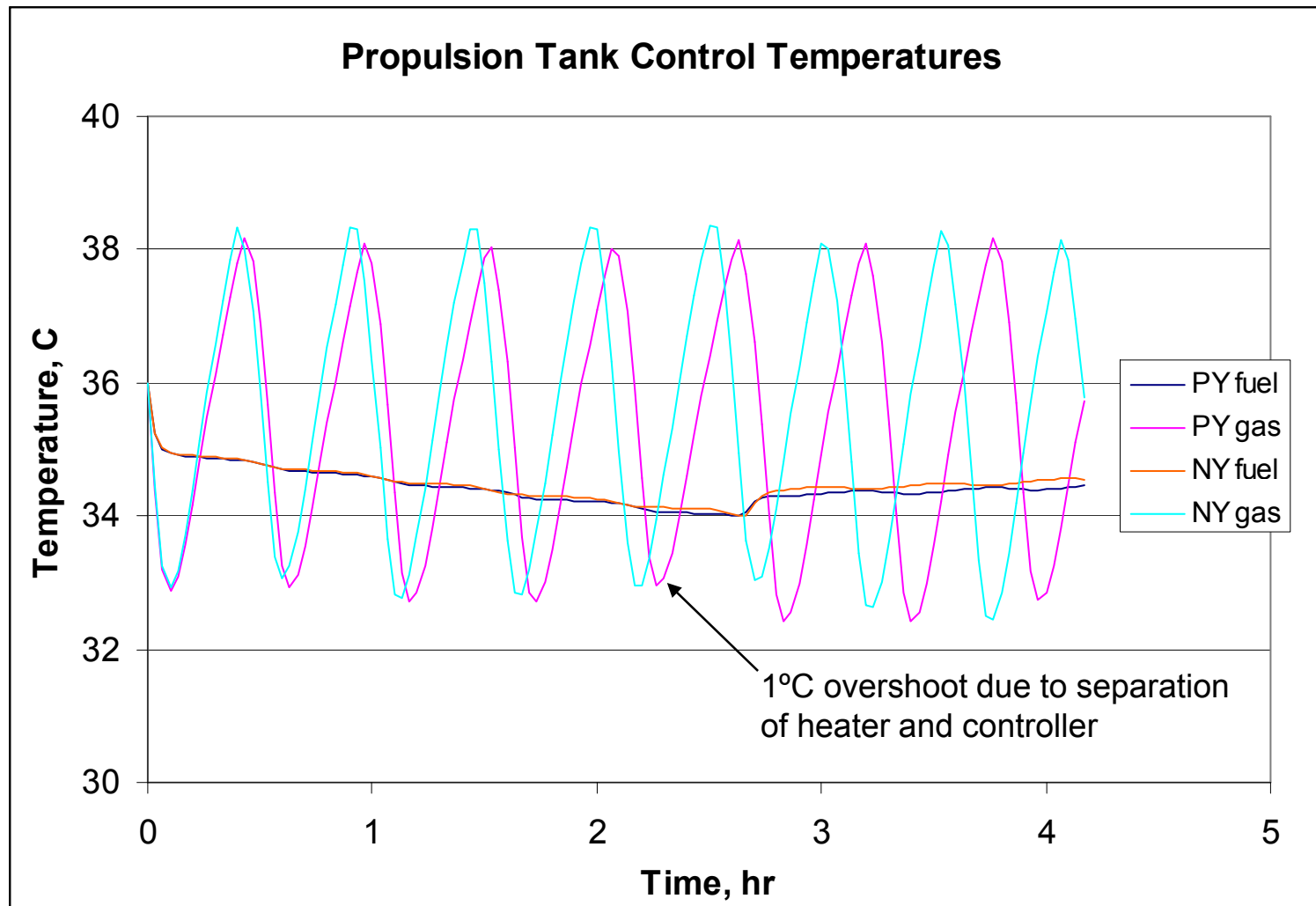
Fuel, 32°C to 41°C

Gas, 32°C to 49°C





Controllers May Be Out of Phase





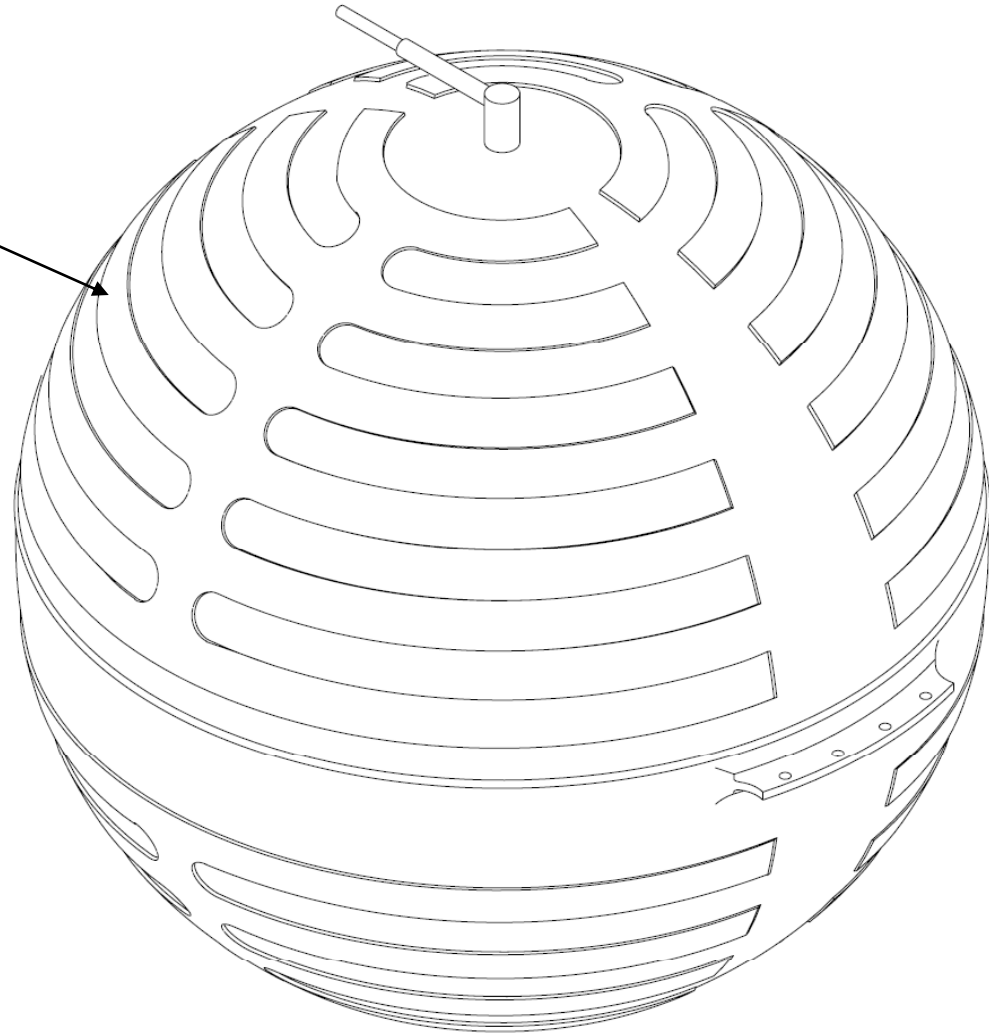
Design: Heaters Cover Large Area



Kapton film heater,
1 of 4

Connect two heaters in
parallel to create a zone
for each hemisphere

Large area keeps power
density low. This builds in
tolerance to voids.





Approximate the sphere with conical segments



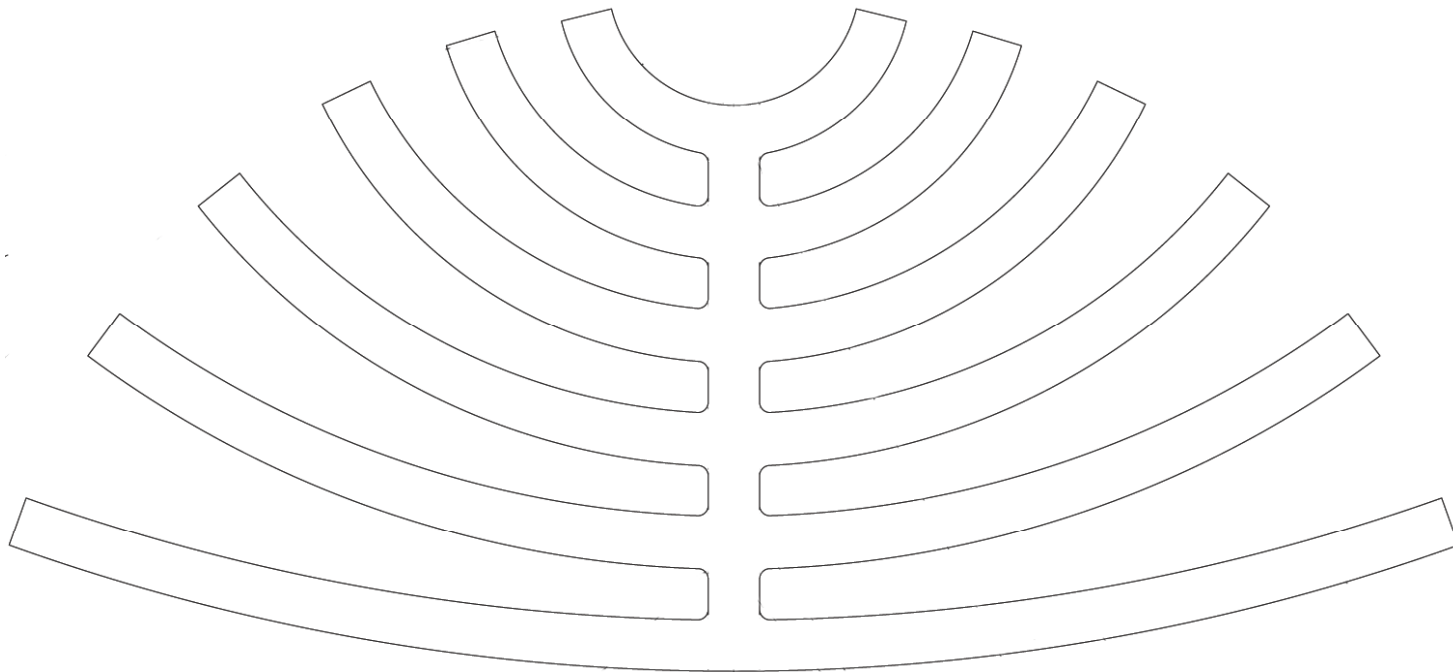
- Conical segments solve the problem of applying a flat heater to a curved surface.
- Hand calculations are sufficient to determine the radii of the segments.
- “Unroll” the conical segments to create the flat pattern.

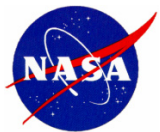


Flat pattern for $\frac{1}{2}$ hemisphere is manageable



Design provides 1 inch spacing around all fingers.
Successful installation requires no wrinkles and no
overlap of heaters.





Verify: Check the fit with a trip to ATK





Install with acrylic adhesive



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- Tayco, the heater vendor, applies acrylic adhesive prior to delivery
 - Alignment is tricky, but is achieved with a little patience.
 - Light pressure and corner staking complete the job.



Installation is successful





Conclusions



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- Thermal analysis yields two 13W heater zones.
 - Entire tank is predicted to have acceptable temperatures.
 - Design proceeded from hand calculations to a fit check at the tank vendor.
 - Installation is complete.
 - Heaters are ready to fly to Mars.